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MEASUREMENTS

SIGNAL GENERATOR-MODEL 78-FM

M-243

Operating INSTRUCTIONS

MP MASTER

MA25118

MEASUREMENTS CORPORATION

BOONTON NEW JERSEY

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OPERATING INSTRUCTIONS

for

MEASUREMENTS MODEL 78-FM

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

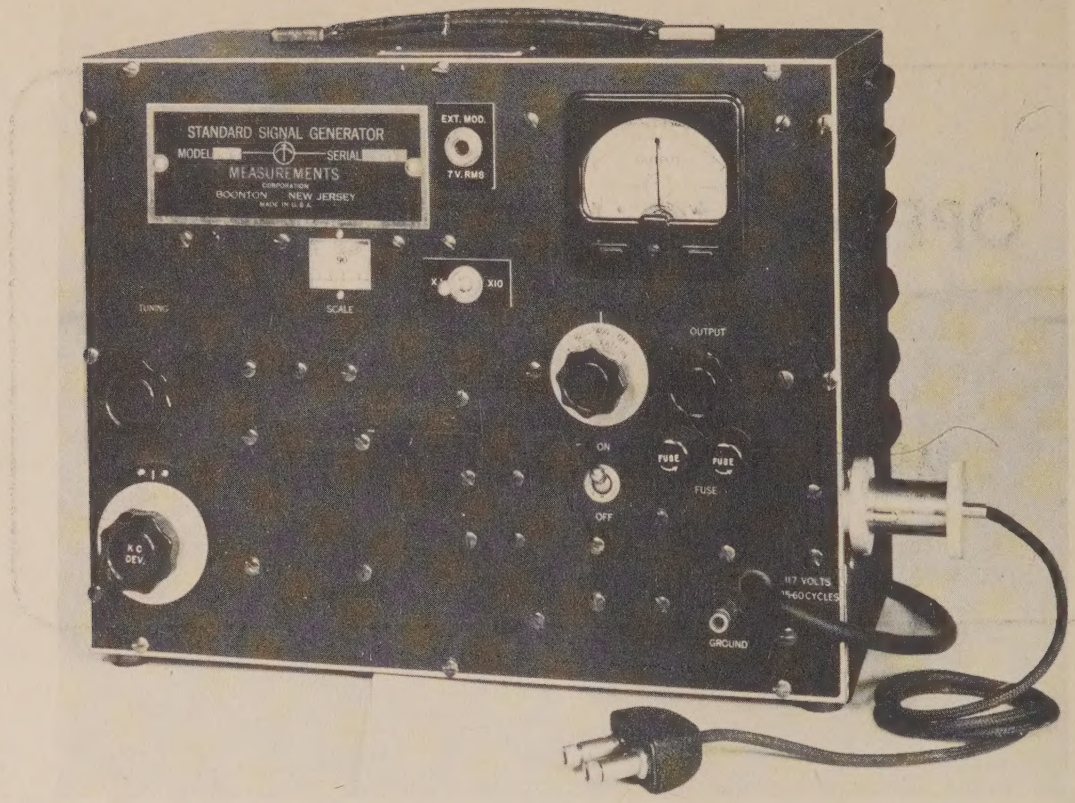
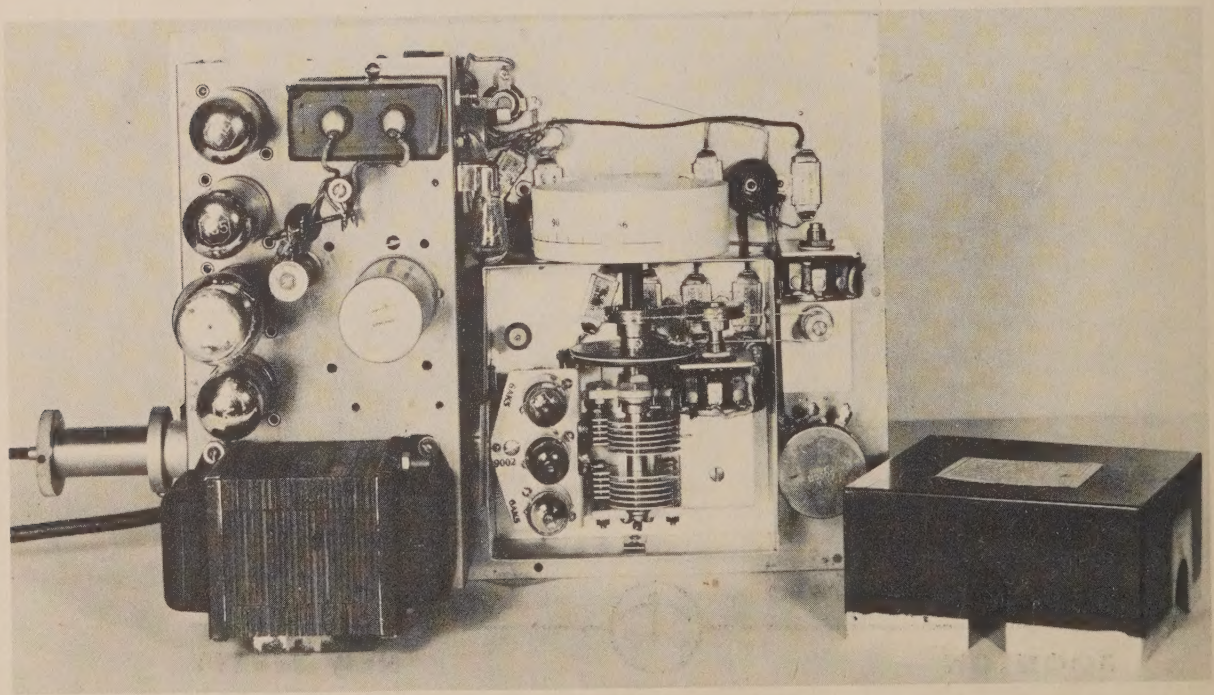


Figure 1 - FRONT VIEW OF MODEL 78-FM



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GENERAL DESCRIPTION

1. INTRODUCTION

a. This handbook describes the basic operation and construction of the Model 78-FM Standard Signal Generator. The Model 78-FM is a frequency modulated signal generator operating directly at carrier frequency. Since no beat frequency oscillators are involved, there are no spurious components present in its output other than small amounts of simple carrier harmonics.

b. Though designed as a laboratory standard, the Model 78-FM is also suitable for use in production testing.

2. GENERAL CHARACTERISTICS

a. CARRIER FREQUENCY RANGE

(1) ~~86~~ 150 to ~~108~~ 165 megacycles in one band. Tuning ratio of only 1.3 to 1.

(2) Individually calibrated tuning scale, accurate to within ±.5%.

b. CARRIER OUTPUT SYSTEM

(1) The mutual inductance attenuator is calibrated directly in microvolts across the output binding posts at the end of the output cable. Since this 34 ohm cable is terminated at both ends, the output impedance is 17 ohms, and the output calibration will be correct as long as the load connected is several times higher. The relative accuracy of this attenuator system is very good, since it depends only upon the diameter of the attenuator tubing. The absolute accuracy of the Model 78-FM is limited to ±20% because of the use of oscillator grid current as an indication of carrier output. If the output meter is set on the red line, the output will be approximately 10% high at 86 megacycles and 10% low at 108 megacycles.

The shielding and filtering of the Model 78-FM is adequate for measurements down to one microvolt. The stray signal with the attenuator all of the way out should be less than 0.1 microvolt.

c. MODULATION SYSTEM

(1) This signal generator is arranged only for frequency modulation or cw operation. The incidental amplitude modulation with deviation of 75 kc is less than 5%.

(2) Two reactance tubes directly across the carrier oscillator provide frequency deviation up to 400 or 500 kc over most of the tuning range. This deviation varies with carrier frequency, and in the 78-FM a correction potentiometer is ganged to the main tuning control, so that it is possible to calibrate the main deviation potentiometer directly in kilocycles.

(3) The deviation potentiometer has a scale from 0 to 30 kc deviation. This means that for internal modulation of either 400 or 8200 cycles the peak excursion of the carrier either side if its center frequency will be that value as read directly on the deviation dial. For deviations greater than 30 kc the multiplier switch directly under the external modulation jack should be thrown to the x10 position and the deviation dial readings must then be multiplied by ten.

(4) The deviation dials are all individually calibrated. The accuracy of deviation calibration is ±10% with the internal audio oscillator. The relative accuracy with external modulation is ±5% plus any error made in determining the magnitude of the 7 volt rms source applied to the external modulation jack. No pre-emphasis is provided.

(5) Total audio harmonic distortion as determined by a very carefully constructed discriminator and distortion measuring equipment is less than 2% when using the internal modulation source at 75 kc deviation. This total harmonic distortion will be less than 1% if source distortion is less than 0.25%.

(6) The frequency response of the frequency modulator is flat within two db from d.c. to 15,000 cycles. The transient response is excellent; however, large square wave deviations at 5 kc as well as large sinewave deviations at 15 kc require band widths in excess of those normally provided by most commercial f-m receivers. When using a square wave generator as an external source, approximately 20 volts peak to peak (as indicated on an oscilloscope or our Model 67) will permit direct reading of the deviation dial. When using a Model 71 Square Wave Generator it is advisable to insert a small 9 volt

battery in the audio connecting lead to remove the d.c. component and provide substantially symmetrical deviation. The negative terminal of this battery should be connected to the square wave generator "hot" terminal.

d. TUBES

One type 9002 r.f. oscillator
One type 6AK5 f-m modulators
One type 7Y4 rectifier
One type VR-150-30 voltage regulator
One type 7L7 amplifier
One type 7C5 modulator

e. POWER SUPPLY

117 volts, 50-60 cycles
Fuses: 2 type 3 AG 1 amp.

f. DIMENSIONS

10" x 13" x 7"

g. WEIGHT

Approximately 25 pounds

3. TUBE REPLACEMENT DATA

a. Replacement or changing the position of the 6AK5 reactance tubes or changing the 9002 oscillator tube should be avoided if possible, since either one will affect the deviation calibration and distortion. If the 6AK5s must be replaced, the new tubes should be chosen to give less than 1% total distortion at ±75 kc. deviation and less than 5% at ±300 kc.

After replacement of either the 6AK5s or the 9002 the deviation calibration should be reset by adjusting the 3K ohm deviation calibration pot. in series with the 5K ohm deviation pot.

Deviation calibration can be set by tuning the carrier in on a narrow band width receiver and then applying 3466 cycle sine wave modulation. The deviation calibration pot. should be adjusted so that the carrier goes thru the third null at ±30 kc. on the deviation dial.

The output calibration will be slightly affected by changing the 9002, but if an average tube is used the error will probably be less than that incurred in trying to reset the output.

If a suitable method of measuring .1 volt at 100 Mc. is available the attenuator should be set at 100K microvolts and the output control set for maximum output. The 15K ohm output meter shunt (stamped "output meter cal.") should then be set so the output meter reads between the "P" and the "U" in the word "output". Set the meter back to the red line using the output control. The set screw on the back of the knurled portion of the attenuator should be loosened and the attenuator loop adjusted in or out to give .1 volt output. The loop should be oriented for maximum output.

Changing either the 9002 or the 6AK5s will change the frequency calibration. This can be made nearly as good as it was originally by slipping the dial slightly. This is best accomplished by loosening the screw in the middle of the dial drum as seen from above.

b. If either the 7L7 or the 7C5 must be replaced the audio voltage should be checked at the panel jack marked EXT. MOD. The plug used to pick up the voltage must be inserted just far enough to make contact, but not far enough to cause the jack to open the circuit. The voltage at this point should be 7 volts RMS and the distortion should be less than 1% at 400 cycles. This voltage can be adjusted over a limited range using the 3K ohm audio feedback control pot. (Stamped "Audio Osc.").

See page 23 for Descriptive Article of Model 78-FM.

PROPOSED PROCEDURE FOR THE MEASUREMENT OF THE PERFORMANCE CHARACTERISTICS OF FREQUENCY MODULATED RADIO RECEIVERS

This instruction book is to define the terminology, equipment, operating conditions and procedures employed in gathering data on the performance characteristics of FM radio receivers.

SECTION I

Brief description of the test precedure.

SECTION II

Definition of special terminology as used in these instructions.

SECTION III

Specification of the salient characteristics of testing apparatus required for the gathering of the requisite data.

SECTION IV

Specification of the receiver operating conditions, receiver adjustment and measurement of input and output.

SECTION I

TEST PROCEDURE

In preparation for the making of the tests required for the gathering of the data as outlined in this section, the f-m radio receiver must be set up with appropriate vacuum tubes, operated with appropriate supply voltages and adjusted generally in accordance with Section IV of these instructions.

A signal generator, dummy antenna and output load and indicator of such characteristics as are given in Section III must be provided and the required measurements made in accordance with Section IV.

In order to minimize the possibilities of ambiguity in the interpretation of these instructions there are reviewed in Section II the special terminology used in the following brief enumeration of the several test procedures.

(A) DATA SHEET. ITEMS 4, 5, 6

TUNING RANGE

The radio receiving tuning control is successively set for the respective minimum and maximum carrier frequencies in each tuning range, which it is capable of receiving. At each setting, the signal generator is tuned to the frequency at which the receiver gives minimum noise, and the signal frequency recorded as Items 4, 5, 6.

(B) DATA SHEET. ITEM 12

SENSITIVITY

The sensitivity test input is measured with the aid of a standard signal generator at three test frequencies in each tuning range, one at the middle and one near each end of the band. This should be recorded as Item 12.

(C) DATA SHEET. ITEM 13

CO-CHANNEL INTERFERENCE

In order to observe completely the interference resulting from the simultaneous reception of two signals, both desired and interfering signals must be present during the test. This is the condition under which is made the two-signal cross talk test which, therefore, deals with the type of interference in which the modulation of the interfering signal is heard in addition to that of the desired signal. The test determines the greatest interference input which may be permitted without the interference modulation output power exceeding 0.001 of the desired modulation output power, both desired and interfering signals being modulated to the same degree.

For this test, the f-m radio receiver is tuned to 100 Mc. with the first signal generator set at 500 μv at 100 Mc. The receiver volume control is adjusted to give normal test output when the signal is modulated 30 per cent at 400 cycles, after which the modulation is switched off.

An interfering signal input voltage is then applied at the following frequencies to the receiver by the second signal generator in addition to the desired signal carrier which remains unchanged:

FREQUENCY	USUALLY CALLED
100 Mc.	Co-channel
100 Mc. +200 kc.	Adjacent Channel
100 Mc. -200 kc.	" "
100 Mc. +400 kc.	Second Channel
100 Mc. -400 kc.	" "

Co-channel matching of the two signal generators shall be assured by zero-beat equalization of the frequencies of the two unmodulated generators, after which modulation can be applied to the interfering signal generator.

The interfering signal is frequency modulated 30 per cent at (22.5 kc. deviation) 400 cycles. The interference test input voltage, which gives interference test output at 400 cycles, is observed and noted in Item 13. Where the interference input is in ecesss of 0.1 volt, its value need not be determined but may be recorded in Item 13 as "0.1 (-) volts".

The above tests with the first signal generator set at 50 μv and again at 10 μv are to be repeated.

(D) DATA SHEET. ITEM 16

MAXIMUM UNDISTORTED OUTPUT

Amplifier Distortion: With 500 μv input at

30 per cent modulation, determine maximum undistorted output, see SECTION II, (E).

High-Modulation Distortion: This measurement should be made successively at the three standard input levels of 10, 50, and 500 uv.

Turn back audio gain control until either:

(a) Distortion is 3 per cent in voltage, see SECTION II, (E); OR

(b) The output is 10 per cent of maximum undistorted output.

If maximum accuracy is desired, use the condition that gives the higher voltage.

Measure the distortion.

Increase the modulation to 100%, keeping the same power output by manipulation of the audio gain control and again measure distortion making sure that the tuning is still correct after the boost in the modulation.

(E) DATA SHEET. ITEM 17

ELECTRIC FIDELITY

The electric fidelity test shows the manner in which the electric output of an f-m radio receiver depends on the audio frequency of modulation.

For this test, the f-m radio receiver is tuned to a 500 μv signal at 100 Mc., modulated 30 per cent at 400 cycles. The receiver volume control is adjusted to give normal test output. The modulation frequency is varied continuously from 30 to 15,000 cycles while maintaining the degree of modulation constant at 30 per cent and the output is observed and noted.

The receiver output is measured in terms of current or voltage in a standard dummy load. Repeat test in terms of voltage across or the current in the voice coil of the loud speaker. In the latter case, the loud speaker should be located in its baffle or cabinet, with the receiver chassis in place. The data should indicate which load is used.

For this test it is unnecessary to make or plot the observations below -20 db or 10 per cent of the value at 400 cycles, although further observation may be otherwise desirable. When the output voltage is measured across the loud speaker in this test the relative output in decibels is taken as 20 log10 of the voltage.

If the electrical fidelity curve has decided peaks or overloading is otherwise indicated, the observations should be made at lower levels and the level at 400 cycles noted and reported.

The electric fidelity curve is plotted with audio frequency as absicissae and relative output voltage or current as ordinates. The ordinates are plotted in decibels or in per cent of voltage or current, taking normal test output at 400 cycles as zero decibels or 100%. In the former case, the scale of ordinates should be uniformly divided; in the latter case, the scale may be logarithmically or uniformly divided. The scale of abscissae should be logarithmically divided.

If hum or noise is present in appreciable amount during the fidelity test, a suitable correction should be made.

If the receiver has one or more manual tone controls, the test should be made with the tone controls so set as to give flat response at high and low frequencies.

The electric fidelity curve may be submitted with the report, or the electric fidelity as defined in Item 17 should be determined and reported.

(F) DATA SHEET. ITEM 19

SPURIOUS RESPONSES

This test is properly classified as a selectivity or interference test, although its procedure is that of a sensitivity test.

With the f-m radio receiver tuned to 100 Mc., the frequency of the signal generator should be continuously varied over a wide frequency range to discover if the receiver responds at frequencies other than the one to which it is tuned. These other frequencies are called spurious response frequencies. Each spurious response frequency is noted and the spurious response sensitivity test input is measured as in the sensitivity test, provided it is smaller than one volt. Its ratio to the sensitivity test input at 100 Mc. should be computed, and is called the spurious response ratio. This ratio should be expressed in decibels and recorded as Item 19.

a. Image Response

Superheterodyne receivers are generally responsive to two frequencies whose difference from the local-oscillator frequency is equal to the intermediate frequency. One of these

(usually the lower) is the desired-signal frequency, and the other is called the image frequency. This is a special case of a spurious response frequency commonly termed "image response ratio". Its value, expressed in db, should be determined and recorded in Item 19a.

b. Intermediate Frequency Response

Another special case of a spurious response frequency in superheterodyne receivers is that due to the sensitivity of the receiver to signals at the frequency of operation of the intermediate frequency amplifier. The test procedure is that briefly outlined above; the value of this spurious response ratio is expressed in db and noted in Item 19b.

Other spurious responses that are brought to light in this test should be reported along with a brief characteristic of the conditions under which they occur under Item 19.

(G) DATA SHEET. ITEM 14

SQUARE-WAVE TESTING

Since f-m receivers are capable of superior audio performance, a square-wave test for the purpose of revealing transient response shall be applied. While a square-wave test does not reveal any information that cannot be obtained from other more conventional tests, it gives the information more graphically, more simply, and with less effort.

For this test, the standard-signal generator, operating at 100 Mc. carrier, shall be 30% frequency modulated by square waves having, respectively, repetition rates of (a) 60 cycles, and (b) 1000 cycles.

With the receiver operating as in (E), use a cathode-ray oscilloscope instead of a vacuum-tube voltmeter for indication.

SPECIAL NOTE

To synchronize an oscilloscope with the Model 78-FM the plug on the oscilloscope lead should be inserted into the external modulation input jack of the signal generator so contact is made by the tip of the plug just touching the "hot" section of the jack but not opening it.

The data obtained for this test shall be submitted in the form of photographs or tracings of the two oscilloscope response patterns one for each of the two repetition rates.

(H) DATA SHEET. ITEM 24

INTERMODULATION TESTS

Recent recognition of the prevalence of not necessarily harmonically-related modulation products in the output of audio systems and radio receivers points up the need for intermodulation tests on f-m receivers, which are inherently capable of faithful audio quality reproduction.

To make these tests, two audio frequencies, not harmonically related to one another, should be employed as the modulation source for a signal generator. The test should be made twice, once with these frequencies located in the low end of the audio band and once with them located near the high end, with the loudspeaker as a load.

When the two modulation frequencies are low, one of them should be the frequency of the loudspeaker resonance and the other a frequency which is equal to BF$\pm$ the loudspeaker resonance frequency. The frequency of the loudspeaker resonance is that frequency at which the low-frequency voice coil impedance peak occurs as the speaker is normally mounted in its cabinet.

For the high audio-frequency measurement, one audio frequency should be in the region of 5 kc and the other in the region of 5 kc + BF. If the intermodulation response is found to be very low at the first-chosen high audio frequency, the two frequencies should be moved a sensible distance in each direction from the first-chosen point to ascertain whether the intermodulation products increase. This is because a curve of intermodulation products against one of the two frequencies often shows one or more sharp minima caused by cancellation effects. The high-frequency intermodulation test must be taken as to give a representative result.

The above-specified pairs of frequencies have been chosen so that either the sum or the difference beat frequency will be BF. This is done, thus so that a single amplifier, tuned to 400 cycles or 1 kc, can be used as the detector of intermodulation products. If a wave analyzer is available, this amplifier will not be needed.

For both sets of measurements, low- and high-frequency, the output of the signal generator shall be 500 uv. Adjust the volume control of

the receiver to give the same maximum output obtained as in I(D), with the signal generator frequency modulated to 100% at 400 cycles.

The audio inputs to the standard-signal generator shall be adjusted to such a level that each of the two contemporaneous modulating frequencies will give 30% frequency swing. During the measurement, both frequencies shall modulate the signal generator simultaneously.

Record the 400-cycle or 1-kc (sum or difference) voltage as a percentage of the arithmetical sum of the two voltages of the wanted signals. Proper allowance must be made for losses in filters. The higher wanted signal must have been so adjusted as to produce the maximum response from the detecting amplifier.

(J) DATA SHEET. ITEM 22

IMPULSE NOISE SUSCEPTIBILITY

1. Purpose:

The purpose of this procedure is to set up a recommended method of measuring susceptibility of f-m and television receivers to impulse type noise.

2. Method:

Pulse modulated carrier shall be applied simultaneously with the desired signal to the receiver input. The necessary ratio of interfering pulsed carrier to desired carrier (applied through a suitable dummy antenna) shall be determined by adjusting for the specified peak signal to interference output ratio from the receiver.

3. Frequency Modulation Receiver:

3.1 Deviation shall be 30% system capability at 400 cycles.

3.2 Pulse width shall be 40 microseconds.

3.3 Pulse repetition shall be 60 per second (To avoid beats).

3.4 Pulse modulation shall be obtained by pulsing an amplifier to avoid frequency shift present in simple pulsed oscillators.

3.5 (a) With the desired carrier deviated 30% of system capability (i.e., ± 22.5 kc.) at 400 cycles, the peak-to-peak audio output is measured on the 'scope.

(b) The deviation is removed from the desired carrier (which is still applied to the receiver). In addition the pulse modulated carrier is applied and increased until the balanced peak-to-peak pulse output, as seen in the 'scope, is down 10 to 1 (i.e., 20 db) from the desired peak-to-peak signal (400 cycles) output.

3.6

3.6.1 Data should be secured with signal levels of 1, 3, 10, 30, 100, 300, 1000, and 3000 microvolts of desired carrier except where receiver sensitivity precludes measurements at the lower levels.

3.6.2 Data should be plotted on 3 cycle log paper with microvolts of desired signal along the vertical axis and microvolts of pulsed signal on the horizontal axis.

3.6.3 Serious curvature or discontinuities may result from detuning and beats. Measurement should be rechecked, if these effects are present.

(K) DATA SHEET. ITEM 25

RANDOM NOISE SUSCEPTIBILITY AND FM IMPROVEMENT FACTOR

I. Random noise susceptibility is a measure of the inherent signal to noise ratio power, and it is customarily referred back to the input in db above thermal in the dummy antenna. This ratio is therefore independent of dummy antenna resistance and bandwidth. The noise factor may be obtained in three different ways:

1. The noise factor may be calculated from noise measurements made ahead of the limiter exactly as for an a-m receiver. The procedure is to

a. Measure the carrier wave input (in terms of the "available power input" from a signal generator) required to produce an output power r + 1 times that obtained with the carrier wave removed, where r is any convenient ratio.

It should be noted that the noise factor may be measured with any dummy antenna impedance desired. However, a certain impedance gives the best noise factor and this is the value usually meant by the noise factor of the receiver. The impedance required may not correspond to an impedance match.

Thus there are several values of noise factor possible; the best value, the value using a specified nominal impedance and the value using an impedance match. Conceivably these may be all different. A receiver specification must be depended upon to distinguish which meaning is intended.

b. Measure the signal channel effective noise bandwidth.

c. Calculate the available noise power input from the apparent series resistance of the dummy antenna in a bandwidth equal to the equivalent signal channel noise bandwidth.

d. Calculate the noise factor which is equal to the signal power input divided by r times the noise power from the dummy antenna. Even if image response and other responses are present, calculate the available noise power from the dummy antenna using only the signal-channel effective noise bandwidth. The image and other responses will contribute to the actual noise present and hence increase the noise factor over the value obtainable in the absence of such responses.

2. The noise factor may be calculated from measurements made ahead of the detector with a noise-generating diode connected across the dummy antenna. If the diode has appreciable impedance, this impedance should be considered as part of the dummy antenna impedance. It is operated with sufficient plate voltage so that the plate current is temperature limited at all times. The cathode temperature is adjusted by varying the filament current until the noise output power is r + 1 times that obtained with the diode turned off where r is any convenient ratio. The mean square noise current from the diode is calculated as follows:

$$I_n^2 = 2eI\Delta f$$

where Δf = the effective noise bandwidth
e = the charge on an electron
I = the direct current in the diode

Thus the available noise power from the diode is:

$$P_d = \frac{I_n^2 R}{4} = \frac{eIR\Delta f}{2}$$

The available noise power from the dummy antenna resistance is:

$$P_r = kT\Delta f$$

The noise factor is then

$$F = P_d/P_r = \frac{eIR\Delta f}{2kTr\,\Delta f}$$

$$= \frac{eIR}{2kTr}$$

If appreciable response exists at the image frequency or at frequencies near the oscillator harmonics, the above equation should be modified to the following:

$$F = \frac{eIR}{2kTr}\,\frac{\Delta f_2}{\Delta f_1}$$

where Δf_2 = the total effective noise bandwidth
Δf_1 = the signal channel effective noise bandwidth

3. The noise factor can be calculated from measurements made after the detector with a single sideband (with carrier) signal generator. (The single sideband signal generator may consist of two separate unmodulated signal generators but some trouble might be experienced with drift, since an accurate frequency separation is required. A preferred single sideband signal generator is one producing the signal by conventional methods of modulating, heterodyning and filtering. The procedure for obtaining the noise factor is as follows:

a. Measure the single sideband available power (preferably using a rather high audio modulating frequency and a low percentage of modulation) required to produce an audio power output, (r + 1) times the audio power output with carrier and noise only on the input, where r is any convenient ratio.

b. Measure the effective signal channel noise bandwidth through the r-f and a-f circuits. This measurement may be made with a fixed carrier, varying the modulating frequency used to produce the single sideband. (If the r-f circuits are much wider than the audio circuits, then the overall effective noise bandwidth is just twice the effective noise bandwidth of the audio amplifier using the frequency of modulation in the single sideband available-power measurement as the reference frequency.)

c. Calculate the noise power obtained from the dummy antenna resistance in a frequency band equal to the effective noise bandwidth.

d. The noise factor is the ratio of the available power of the single sideband to r times the available power from the dummy antenna resistance. Even if image response and other responses are present, calculate the available noise power from the dummy antenna using only the signal-channel effective noise bandwidth. The image and other responses will contribute to the

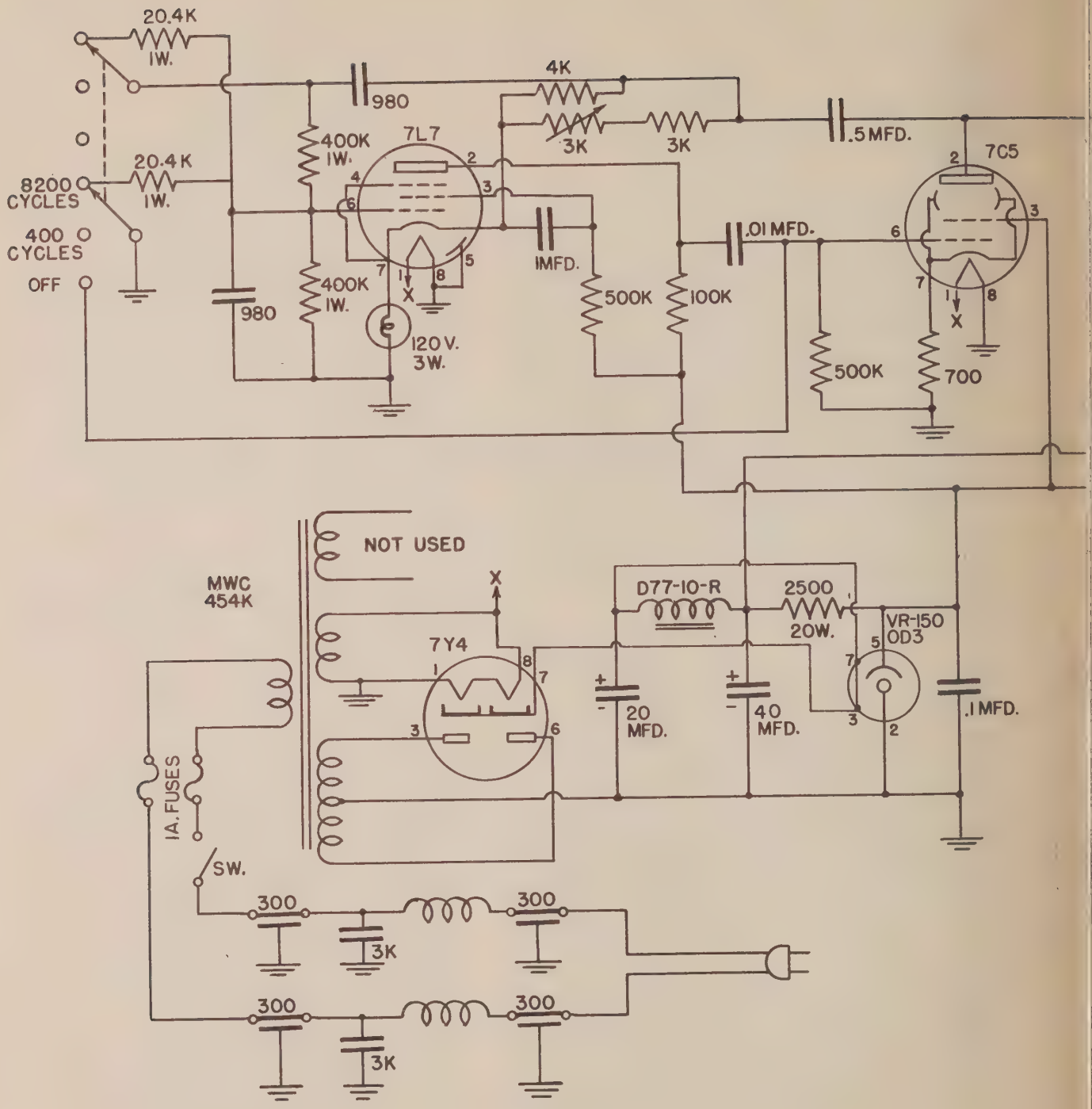
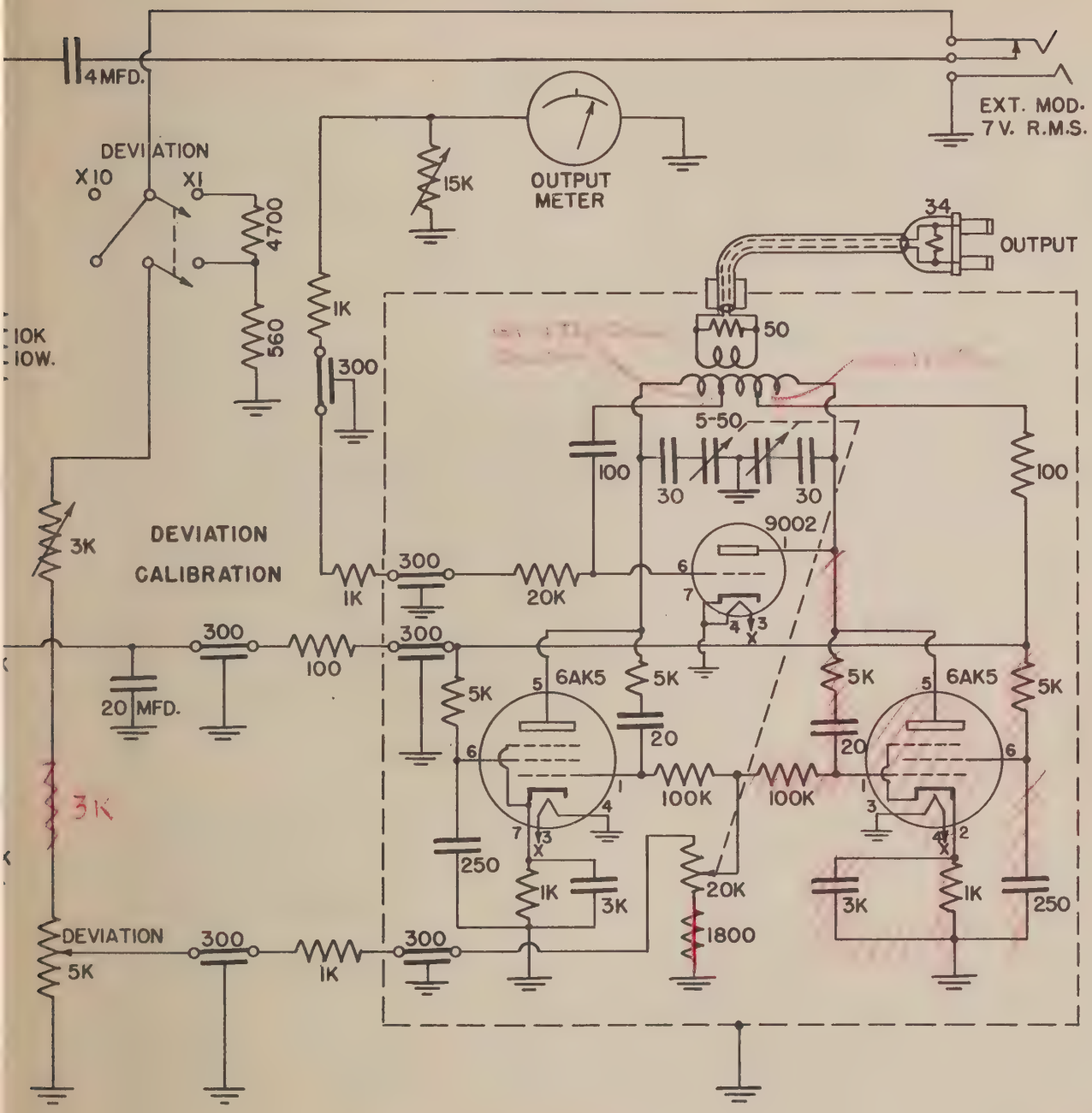

20.4K
1W.
980
4K
3K
3K
.5MFD.
400K
1W.
7L7
7C5
20.4K
1W.
8200
CYCLES
400
CYCLES
OFF
980
400K
1W.
1MFD.
.01MFD.
500K
100K
500K
700
120 V.
3W.
NOT USED
MWC
454K
X
D77-10-R
2500
20W.
VR-150
OD3
7Y4
20
MFD.
40
MFD.
.1MFD.
1A. FUSES
SW.
300
3K
300
300
3K
300

Figure 3 - Wi



UNLESS OTHERWISE SPECIFIED
CAPACITIES ARE IN MICRO-MICRO FARADS
RESISTANCES ARE IN OHMS
K = X1000

M-24

AGRAM MODEL 78-FM

actual noise present and hence increase the noise factor over the value obtainable in the absence of such responses.

II. FM Improvement Factor is a measure of the random noise reduction of an f-m receiver compared to an a-m receiver having similar fidelity characteristics (assuming the same r.f. circuits and the two gains adjusted so that the same audio output is provided in each case for similar percentages of modulation).

The FM Improvement Factor can be measured in two ways:

1. The factor may be calculated from measurements made with an a-m detector substituted for the f-m detector. The procedure is:

a. Using the f-m detector, make a measurement of noise level and signal level in the output circuit, the noise being measured with the modulation removed. The amplitude of the carrier wave on the input should be several times that of the noise.

b. Substituting an a-m detector and audio amplifier (ahead of the limiter) and an a-m signal generator, adjust the carrier to the same level, adjust the modulation to the same percentage of the peak nominal value, adjust the gain of the receiver for equal audio signal output and then remove the modulation and measure the noise.

c. The ratio of the noise in the a-m case to the noise in the f-m case is the f-m improvement factor.

Obviously, the same fidelity should be used in the two cases. Pre-emphasis and de-emphasis present a complication. It is recommended that when pre-emphasis is used in the f-m system under test, it be utilized in the f-m portion of the test. It should not be used in the a-m portion of the test so as to retain simplicity in the standard of comparison. The frequency of the audio signal may be chosen at random without affecting the result providing the overall fidelity of signal generator and receiver is the same in the a-m case as in the f-m case.

The f-m improvement factor, as measured above, may vary with the position of the carrier frequency, particularly if no limiter is used. To bring out this point it may prove to be desirable to plot a curve of f-m improvement factor versus carrier tuning across the pass band.

2. The f-m improvement factor may also be calculated from measurements made using an f-m signal generator. The procedure is:

a. Using an unmodulated carrier on the input of several times the magnitude of the input noise, make a measurement of the noise power output.

b. Using a 400 cycle tone to frequency modulate the carrier to 10% of nominal peak deviation, measure the ratio (r + 1) by which the power output increases. Record the generator available power input "P_{FM}", which is equal to ten r times the available thermal noise power of the dummy antenna "P_r" times the noise factor "F" divided by the f-m improvement factor "I".

c. Measure the noise factor by one of the methods given above.

d. Calculate the f-m improvement factor using the following formula:

$$I = \frac{10rFP_r}{P_{FM}}$$

(L) DATA SHEET. ITEM 23

OSCILLATOR RADIATION TEST

This is a measure of the voltage, due to the local oscillator of the receiver, that appears across the receiver antenna terminals.

A sensitive voltage indicating device such as a Measurements Model 58 UHF Radio Noise and Field Strength Meter placed across the antenna terminals and tuned to the frequency of the local oscillator of the receiver under test. The voltage measured is recorded as oscillator radiation voltage.

Care should be taken that the indicating device should not respond to any voltage but that directly across the measured set of antenna terminals.

SECTION II

TERMINOLOGY

A. SENSITIVITY TEST INPUT

The sensitivity test input is the least signal input voltage of a specified carrier frequency, modulated 30 per cent at 400 cycles per second and applied to the receiver through a standard dummy antenna, which results in normal test output, as defined below, when all controls are adjusted for greatest sensitivity. It is expressed in microvolts. Output should be obtained through a band-pass filter, and the level of normal test output suitably reduced from the values under II (C) to allow for the loss at fundamental frequency in the filter.

B. INTERFERENCE TEST INPUT

The interference test input is the least interfering signal input voltage of specified carrier frequency, which results in interference test output, as defined below. It is expressed in microvolts. The nature of the interfering signal and of the interference output are determined by the type of interference under investigation and are specified for the interference test described in other sections of these instructions.

C. NORMAL TEST OUTPUT

a. For receivers capable of delivering at least one watt maximum undistorted output, the normal test output is an audio-frequency power of 0.5 watts delivered to a standard dummy output load.

b. For receivers capable of delivering 0.1 to 1 watt maximum undistorted output, the normal test output is 0.05 watt audio-frequency power delivered to a standard dummy output load. When this value is used it should be so specified in the report, otherwise the 0.5 watt value will be assumed.

D. INTERFERENCE TEST OUTPUT

The interference test output is one-thousandth of the power of the normal test output or 30 decibels less than the normal test output. This output is used only in two-signal interference test.

E. MAXIMUM UNDISTORTED OUTPUT

The maximum undistorted output is arbitrarily taken as the least power output which contains under given operating conditions a total apparent power at harmonic frequencies equal to one per cent of the apparent power at the fundamental frequency. (This corresponds to a root-mean-square total voltage at harmonic frequencies of 10 per cent of the root-mean-square voltage at the fundamental frequency, if measured across a pure resistance.)

F. STANDARD INPUT VOLTAGES

Three standard input voltages are specified for the purpose of certain tests as follows:

(a) 10 microvolts or 100 decibels below 1 volt.
(b) 50 microvolts or 86 decibels below 1 volt.
(c) 500 microvolts or 66 decibels below 1 volt.

G. STANDARD TEST MODULATION

The phrase "standard test modulation", in tests on frequency-modulation receivers, refers to a signal that is frequency-modulated at 400 cycles per second with a swing of 30 per cent of maximum rated system swing.

SECTION III

CHARACTERISTICS OF TESTING APPARATUS

Most of the apparatus employed in the testing of radio receivers has become so well standardized that no greatly detailed description of the apparatus is required for the purpose of these instructions. A brief discussion of the necessary ranges, precision of calibration and constants may be found of value and is, therefore, given.

The devices of major importance in such testing comprise the standard-signal Generator, the output indicator, the dummy antenna, and the appropriate output load. For certain tests two audio-frequency oscillators are required as are special circuit elements which are more specifically referred to in the detailed testing instructions. There will also be needed a cathode-ray oscilloscope, a square-wave generator, and certain harmonic-measuring equipment.

In general, the radio receiver under test is coupled to the output terminals of the standard-signal generator through a standard dummy antenna designed to provide impedances closely approximating the average of the impedances of antennas which have been found in actual use. The audio frequency electrical output of the receiver under test is measured in terms of the power delivered to a standard dummy output load. The power may be indicated directly by a milliwattmeter or calculated from the voltage or current at the load. For measurements of electrical output when the background noise is appreciable in comparison to the desired signal output, a band-pass filter, tuned to the desired audio-frequency signal, may be inserted between the standard dummy load and the indicating instrument.

The following general characteristics and limits are indicative of the ranges and tolerances which are desirable and permissible.

A. STANDARD-SIGNAL GENERATORS

Suitable FM Standard Signal Generator such as Measurements Model 78-FM, and Square-Wave Generator such as Measurements Model 71.

B. STANDARD DUMMY ANTENNA

The standard dummy antenna shall be an essentially pure resistance and shall have a value either (1) that which the manufacturer specifies as proper for his receiver, or (2) 100 ohms if no value is specified by the manufacturer.

The signal generator output impedance must be taken into account so that it, plus the resistance of the dummy antenna, will total the proper one of the values just specified.

Stray capacitance or other couplings between the elements of the dummy antenna or between any of these and the signal generator or the receiver under test must be avoided.

The leads used in connecting the standard-signal generator through the dummy antenna to the receiver, should be so short as to introduce negligible voltage drop. They should be shielded to reduce external fields.

C. OUTPUT POWER MEASURING DEVICE

The standard dummy output load is a pure resistance which should be of sufficient power capacity to carry the maximum power output of the receiver with negligible change in its resistance. If provided with taps, these should be sufficiently numerous to allow an adjustment to within 10% of the proper value. The precise value of the resistance of each step should be known.

Copper-oxide rectifier-type, vacuum-tube voltmeters or thermocouple-type ammeters, are all used for measuring the power delivered to the standard dummy load. They may read r-m-s values of current or voltage or directly in decibels. While copper-oxide type voltmeters are subject to temperature and frequency errors these are usually not of sufficient magnitude to affect the measurements seriously.

D. FILTERS

Audio-frequency filters for the various tests herein described may be designed by conventional

methods. Band-pass or band-elimination filters should preferably be provided with tuning adjustments. Each iron-core inductor must be designed with an air gap and with sufficient iron so that at the maximum output level appreciable harmonics are not generated in the filter. The attenuation of the filter at the frequency at which it is used must be known and correction made for its presence.

E. INTERMODULATION TESTING EQUIPMENT

In lieu of appropriate filter systems, a wave analyzer can be used for reading percentage of modulation.

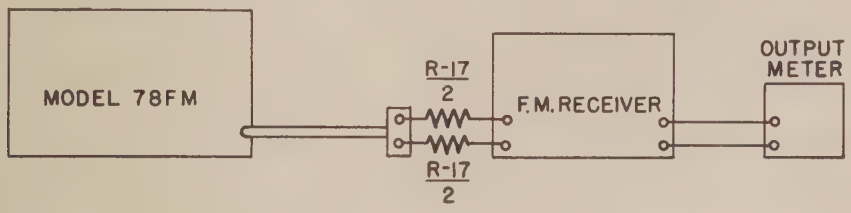


FIGURE-1A

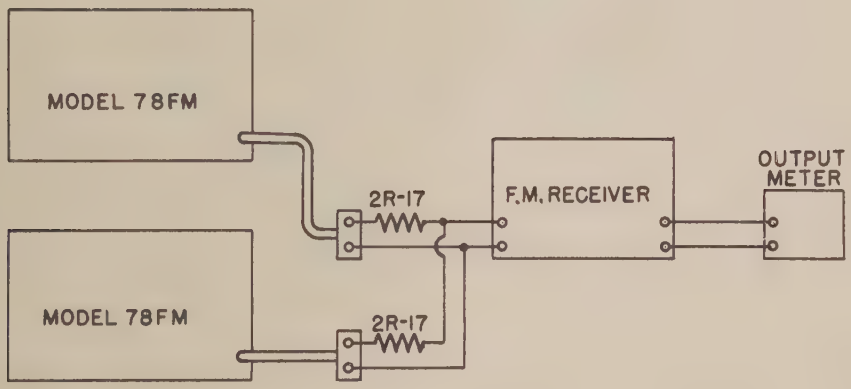


FIGURE-2A

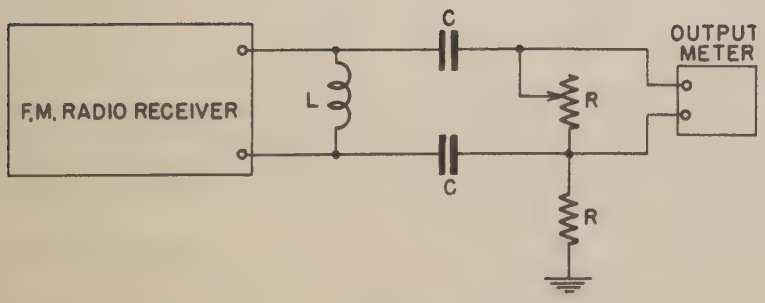


FIGURE-3A

Figure 4 - SCHEMATIC ARRANGEMENT OF TEST APPARATUS

SECTION IV

OPERATING CONDITIONS

1. POWER SUPPLY VOLTAGE

The operating voltage or voltages applied to a radio receiver under test should be held constant at the specified value during measurement of receiver characteristics. The operating voltages given below for the various classes of receivers are the values for normal testing of receivers.

a. Socket Powered Radio Receivers.

The normal test voltage is 117 volts.

In A.C.-D.C. receivers any characteristic of this type of receiver which is affected by the alternate kinds of power supply should be tested with both alternating and direct current and the mean value reported. If the receiver is provided with adjustments for reducing them or ripple in the output, such adjustments should be made

b. Battery Operated Radio Receivers.

1. Automobile Receivers.

The normal test voltage is 6.6 volts at the receiver battery terminals. This voltage should be obtained from a 6 volt battery subject to steady charging at the required rate rather than by use of "dropping" resistors.

2. Farm lighting plant receivers.

This class of receivers includes those designed for operation from the so-called 32 volt farm lighting system. The normal test voltage is 36 volts.

3. Radio Receivers operated from batteries of specified voltages.

This class of battery-operated receivers is intended to comprise those not included in the classes above. Batteries of the type and voltage specified for use with the receiver should be employed. The batteries used should not have abnormally high internal resistance. If a battery cable is not furnished with the receiver, the leads to the batteries should be as short as possible.

2. VACUUM TUBES

The vacuum tubes used should be selected to have the rated values of those characteristics which most affect the performance of the receiver.

B. RADIO RECEIVER ADJUSTMENT

1. TUNING CONTROLS

A receiver is tuned approximately to a desired signal by adjusting the tuning controls until the desired audio-frequency output is obtained either with the least possible radio frequency input power or with the lowest possible setting of the volume control.

The range switch is regarded as a tuning control.

A receiver for frequency-modulated waves is tuned accurately to a desired signal by first tuning it approximately and then adjusting the tuning controls until either the undesired noise is a minimum or the harmonic distortion of the demodulated desired signal is a minimum. In many receivers these two tuning positions coincide. When they do not coincide it should be stated whether the tuning is to maximum noise or minimum distortion.

2. VOLUME CONTROLS

The adjustment of a single main volume control requires no special instructions.

3. TONE CONTROLS

During tests requiring output measurements at 400 cycles only, the tone control should be adjusted to give maximum 400-cycle output. During other tests, the tone control must be adjusted to meet the requirements of the particular test.

C. INPUT MEASUREMENTS

1. RADIO RECEIVER DESIGNED FOR A STANDARD ANTENNA

The input voltage is introduced in the radio receiver from the standard-signal generator in series with a standard dummy antenna as shown in

Figure 1A. The output circuit of the standard-signal generator should have negligible impedance as compared with the standard dummy antenna, unless the output circuit impedance is included as a part of the dummy antenna network. The leads between the dummy antenna and the signal generator must have negligible effects or their effect must be taken into account.

For certain tests of radio receivers two radio-frequency input signals are required simultaneously and consequently, two standard signal generators are employed as shown in Figure 2A. The recommended method is to use very-high-frequency dummy antennas of twice the normal value with each generator. The calibration for equivalent-open-circuit voltage of each generator is made before further connection. The terminals of the two dummy antennas are then connected in parallel and to the input terminals of the receiver. By this arrangement, the impedance connected across the receiver input terminals is the normal value and the equivalent-open-circuit signal voltages are half the values indicated by each generator.

2. RADIO RECEIVER DESIGNED FOR A SPECIAL ANTENNA

A receiver designed for use with a special antenna or special input circuit must be tested with a special dummy antenna or circuit of such constants as simulate the special antenna or circuit. Care should be taken that the method of introduction of signal voltage, as well as the impedance characteristics of the dummy, suitably simulate conditions existing in the use of the special antenna or input circuit. Where a special dummy is used, a statement of the constants employed should be included along with the test data which is reported.

The input to the receiver should be expressed as the r-m-s voltage in microvolts, or alternatively in decibels below one volt, applied to the input terminals of the dummy antenna, the output terminals of the dummy antenna being connected to the receiver.

D. OUTPUT MEASUREMENTS

1. CHOICE OF OUTPUT LOAD

Output measurements of a radio receiver are made in terms of the power delivered to a standard dummy output load, except in special cases where other terms are specified.

A radio receiver not provided with a loud speaker should be tested with a standard dummy load.

The standard dummy load is a pure resistance whose value is equal to the 400-cycle impedance of the loud speaker which is (a) included in the radio receiver, or (b) supplied therewith, or (c) recommended for use therewith. Where an output transformer is connected between the radio receiver and the loud speaker, the output transformer is to be treated as part of the radio receiver.

If the loud speaker impedance has pronounced irregularities of frequencies in the vicinity of 400 cycles, or if the preceding rule cannot be complied with, the standard dummy load is determined by one of the following rules:

a. The load resistance which gives the greatest value of maximum undistorted output.

b. The load resistance recommended by the manufacturer of the radio receiver or of the vacuum tubes used therein.

In case the latter rule is to be followed and there is a transformer between the output vacuum tube and the load, the load impedance should be

$$R_2 = R_1 \frac{(N_2)^2}{(N_1)}$$

where,

R_2 is the standard dummy load resistance in ohms,

R_1 is the load resistance recommended for the output vacuum tube, in ohms.

N_2 is the number of turns on the transformer secondary, and

N_1 is the number of turns on the transformer primary.

In case n output vacuum tubes are connected in parallel, the standard dummy load is R_2/n.

In case 2n output vacuum tubes are connected in push-pull, the standard dummy load is $2R_2/n$.

2. RADIO RECEIVER WITH NO DIRECT CURRENT IN ITS OUTPUT

If the output circuit of a radio receiver is free of any direct current component and is insulated from high direct voltages, a dummy load may be connected directly to the output terminals in place of a loud speaker.

3. RADIO RECEIVER WITH DIRECT CURRENT IN ITS OUTPUT

If the output circuit of a radio receiver carries a direct current component, or if it is connected to high direct voltages, the dummy load should be insulated from the output terminals by the use of the choke coil L and condensers C, as shown in Figure 3A. The values of L and C should be sufficiently great to have negligible effect on the output to be measured. Static charges on the dummy load should be avoided by using leak resistor, r, of negligibly high value.

4. RADIO RECEIVER WITH PUSH-PULL AMPLIFIER OUTPUT

If the output circuit of a radio receiver carries direct current, as obtained from the plates of two tubes operating as a push-pull amplifier, the standard dummy load and the inductance may have center taps. It is then advantageous to connect the ground potential side of the voltmeter to the center tap and observe directly one-half the load voltage.

5. RADIO RECEIVER WITH BACKGROUND NOISE IN ITS OUTPUT

A. If the output power due to the noise is smaller than the output power due to the signal which is to be measured, the increase in reading of the output meter when modulation is applied to the input signal may be used to measure the output power due to the signal. Thus, when using a thermocouple output meter the output power due to the signal is equal to the total power due to the combination of modulated signal and noise, less the output power due to the noise in the presence of the carrier. These powers may be computed from the voltage across or the current in the dummy output load. Where another type of output meter is used, it should be calibrated in terms of incremental power as indicated by a thermocouple instrument.

To express the output in terms of the voltage across or the current through the dummy output load under these conditions of noise, the equations given below may be found of value.

These follow directly from the power relation stated above and given again below.

$$W_o = W - W_n \quad V_o = \sqrt{V^2 - V_n^2} \quad I_o = \sqrt{I^2 - I_n^2}$$

in which W_o, V_o, I_o are respectively the output power, voltage, and current to be measured: W, V, I are respectively the total output, power, voltage, and current which is observed when both noise and modulated signal are present: and W_n, V_n, I_n are respectively the output power, voltage, and current due to the noise.

B. If the background noise power is greater than the output power being measured, it is desirable to use a band-pass filter tuned to the latter to reduce the background noise.

C. The ideal method of selecting a locally generated signal from noise and other disturbances of different frequencies is the use of a synchronously excited electrodynamometer. The field is excited from the original source of the modulation, such as the 400-cycle generator, and the phase of excitation is adjusted for maximum deflection when the signal output of the receiver is applied to the armature. The average deflection then depends only on the signal output corresponding to the excitation. Other output merely causes slight fluctuation of the deflection. This method is especially well adapted to the selection and individual measurement of hum components and harmonic distortion components, the field being excited by synchronized current of the desired harmonic frequency, with other components thoroughly filtered out. Vacuum electrodynamometer circuits have been described in the literature and are well adpated for this purpose.

PROPOSED DATA SHEET

CHARACTERISTICS OF FM BROADCAST RECEIVERS

1. Name of Manufacturer _____

2. Symbol Identifying the Mechanism; Chassis No. _____

   Used on Model No. _____ No. _____
   No. _____ No. _____
   No. _____ No. _____

3. Date of Beginning of Production _____

4. Wave Bands Covered (Frequencies):

   (a) _____ to _____
   (b) _____ to _____
   (c) _____ to _____
   (d) _____ to _____

5. RF System - Number of Selective Circuits and Method of Tuning:

   (a) No. _____ Tuning _____
   (b) No. _____ Tuning _____
   (c) No. _____ Tuning _____
   (d) No. _____ Tuning _____

6. IF System - Frequencies, Number of Tuned Circuits, and Method of Adjustment:

   Freq. _____ kc _____ Circuits _____ Tuning
   Freq. _____ kc _____ Circuits _____ Tuning
   Freq. _____ kc _____ Circuits _____ Tuning

7. Power Supply: AC _____ AC/DC _____ Dry Battery _____
   Storage Battery; Auto _____ Other _____

8. Number, Type, and Function of Type:

9. Antenna System:
   Self-Contained or Built-In Antenna:

   Outside Antenna--Terminations:

   Balanced _____ Impedance _____ (ohms)

10. Automatic Tuning:
    Total No. of Buttons _____

11. Special Features:

    _____

    _____

    _____

CHARACTERISTICS OF FM BROADCAST RECEIVERS - Continued:

12. Sensitivity:

FM: Frequency:

Maximum Deviation Input
Maximum Sensitivity Input
Deviation Sensitivity Input
Quieting Sensitivity Input

13. Selectivity

FM at 98 Mc and at 110 μv desired signal
(a) Co-channel Ratio for 30 db Interference _____ db
(b) Adjacent Channel Ratio for 30 db Interference _____ db
(c) Second Channel Ratio for 30 db Interference _____ db

14. Square-Wave Testing
(a) Photographs or Tracings, 60 cycles and 1000 cycles.

15. Maximum Power Output: _____ watts at 100 Mc.

16. Maximum Undistorted Power Output: _____ watts at 100 Mc.

17. Electrical Fidelity:
(a) Low Frequency for -10 db from 400 cycles _____
(b) Upper Frequency for -10 db from 400 cycles _____

18. Automatic Volume Control Range: At 100 Mc _____

19. Spurious Response Sensitivity:
(a) Image Ratio:
88 Mc. _____
100 Mc. _____
108 Mc. _____

(b) IF Response Ratio:
100 Mc. _____

20. Oscillator Frequency:
FM _*Harmonic above or below (check)
FM _ Harmonic above or below (check)

21. Underwriters' Approved: _____

22. Noise Susceptibility Ratio:
At 1 μv - Pulse to Signal Ratio for 10 to 1 peak to peak output
At 10 μv - Pulse to Signal Ratio for 10 to 1 peak to peak output
At 100 μv - Pulse to Signal Ratio for 10 to 1 peak to peak output
At 1000 μv - Pulse to Signal Ratio for 10 to 1 peak to peak output

23. Oscillator Radiation Test - Microvolts across Antenna Terminals:
100 Mc. _____ Microvolts

24. Intermodulation Tests
100 Mc. Carrier Frequency

Low Frequency % of Intermodulation _____
High Frequency % of Intermodulation _____

25. Random Noise Susceptibility and FM Improvement Factor

---

* Specify harmonic number used of receiver oscillator fundamental frequency, and check if used frequency is above or below signal frequency.

HIGH FREQUENCY FM SIGNAL GENERATOR

Generation of standard signals from 86 to 108 mc for laboratory and production testing of FM receivers

• The future acceptance of FM broadcasting for home reception depends largely on recognition of the three major advantages of this type of transmission, namely:

(1) Higher signal-to-noise ratios,

(2) An extended audio frequency range,

(3) Lower distortion inherent to both transmission and reception.

To fully realize these advantages the testing procedure used for design and maintenance of FM receivers must have several unusual features. The most important item for laboratory and production line uses is the signal generator with its special characteristics:

(1) A noise level from all sources at least 60 db below that of the desired signal output.

(2) A modulation characteristic inherently uniform from dc to 15,000 c/s (within 2 db).

(3) Distortion not exceeding 1% total harmonics when the test signal is frequency modulated 75 kc to either side of center frequency. The range and modulation capabilities must, of course, safely exceed the FCC requirements for transmission in the 86 to 108 mc. band. In this regard it may be of interest to examine the Type 78-FM signal generator that has just been developed by Measurements Corp., Boonton, N. J.

To attain these standards of performance considerable work was first done on equipment and methods of measuring and calibrating FM signals. It was decided to base all deviation calibration on the following sequence:

(1) Establishing a linear frequency modulation with respect to signal generator audio input by measurements using a laboratory standard FM receiver of special design. For this purpose a 30 mc if amplifier and discriminator was designed, using a silicon crystal mixer with two stages of amplitude limiting, followed by a balanced discriminator having a high degree of linearity over a range of ± 400 kc. After heterodyning the FM signal output against an unmodulated signal generator, used as local oscillator, this wide-band if channel easily accepts the maximum deviation of ±300 kc for which the Model 78-FM is designed.

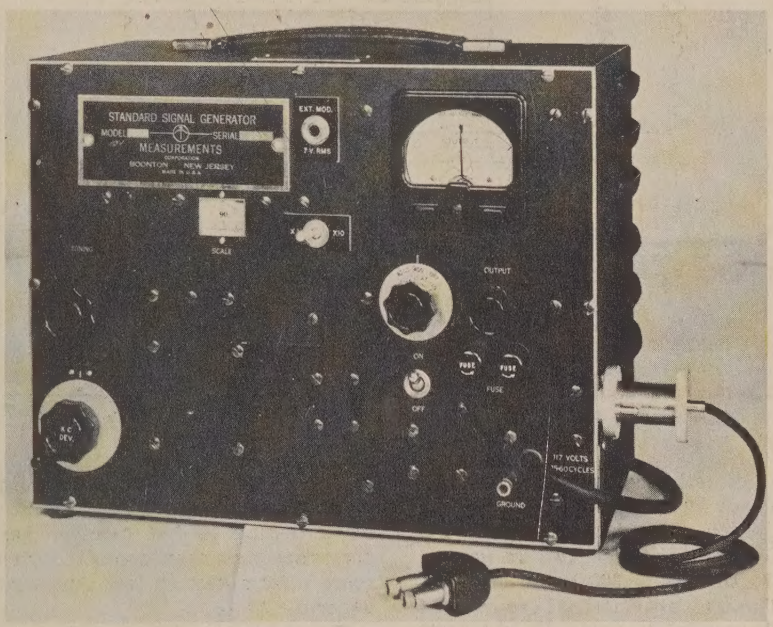


Figure 5. Panel arrangement of a new portable FM signal generator for the 86-108 mc band

(2) The "carrier null" method of FM deviation calibration is next applied, using a tuning fork of exactly 3,466 c/s as modulation source. This frequency yields null points of center frequency when peak deviations of 8.335 kc, 19.132 kc and 30 kc are attained (see nomograph, page 70 of this issue).

(3) Having established a reference point (30 kc) of deviation, and knowing that deviation is linearly related to modulator input voltage, it is now possible to mark the "Deviation Dial" of the signal generator by applying known dc potentials to the input network of the frequency modulating circuit. The primary standard of dc voltage in this case is a Weston potentiometer and standard cell which is capable of establishing voltage values to an accuracy of one part in 10,000.

Since incidental amplitude modulation from the modified Colpitts oscillator used in this instrument was found to be less than 3% at a deviation of 100 kc, no amplitude limiter was considered necessary to assure uniform signal output. However, oscillator "stiffness" does vary with L/C ratio when tuning over the band, therefore it is necessary to adjust the level of input signal to the frequency modulator circuit in some way if the direct-reading deviation dial is to be accurate at any selected carrier frequency. Fortunately, a range of 86 to 108 mc represents a tuning ratio of only 1.3 to 1.

The response of the oscillator to quadrature currents introduced by the reactance tubes does not vary widely over this narrow tuning range and suitable choice of constants has caused this variation to be practically linear. Reference to the accompanying circuit diagram will show a variable potentiometer, R_1, mechanically coupled to the oscillator tuning capacitor. Factory adjustments provide for tracking this linear potentiometer to produce automatic compensation of the audio signal input to the reactance tubes. This maintains the level of actual frequency modulation to within 5% of the values shown by

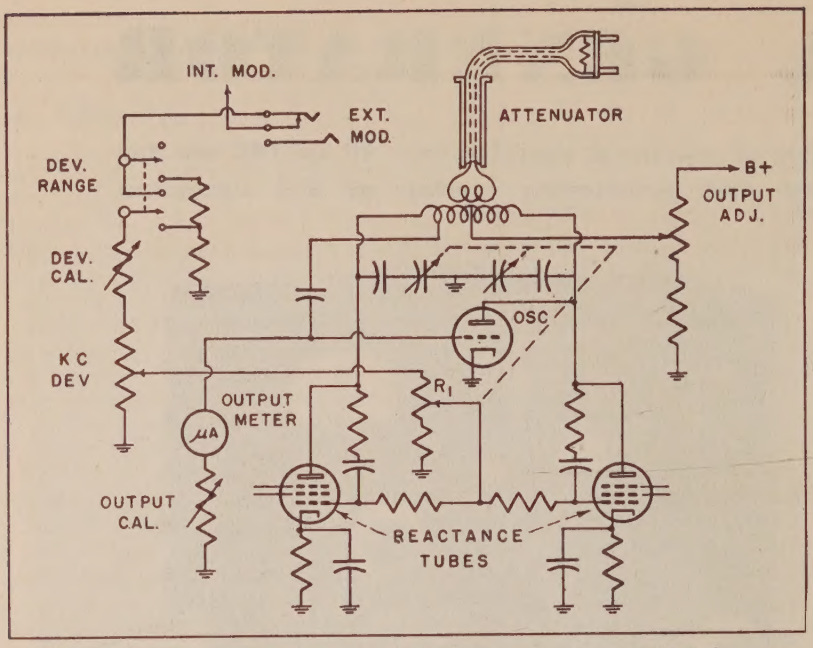


Figure 6. Basic circuit elements of the FM signal generator, showing mutual inductance attenuator

the directly calibrated deviation dial. A switch is provided on the panel, in order that one deviation dial can cover the two ranges of 0±30 kc and 0±300 kc.

Though an internal source of audio modulation at 400 and 8,200 c/s is provided, fidelity runs will require an external variable audio oscillator to deliver exactly 7 rms volts across the 5,000 ohms impedance of the external modulation input circuit. Relative deviation accuracy, when using an external source of frequency modulation, is ±5%, plus any error made in determining the magnitude of the external 7-volt level. Over-all transient response of the Model 78-FM is suitable for square wave modulation of the carrier signal. Square wave testing of FM receiver performance has been found to yield more information in less time than other methods.

The deviation dial may be used as a calibrated vernier frequency control by applying a dc potential of exactly 9.9 volts to the external modulation jack. This suggests a rapid method of selectivity measurement, since reversal of the dc polarity will shift the signal generator frequency above and below the center frequency by an amount directly indicated on the deviation dial.

Signal output is obtained from a transverse type mutual inductance attenuator calibrated directly in microvolts from 1 to 100,000. The attenuator tube will be seen in the accompanying photograph, attached to the output cable at the lower right, and partially withdrawn from the case. Across the innermost end of this tube a small coupling loop is mounted so as to lie opposite the center tap of the oscillator coil.

Movement of the tube varies the inductive coupling between oscillator and loop, and the capacitive component of coupling is effectively eliminated by locating the loop at the electrical center of the coil where the two out-of-phase capacitive fields tend to cancel. Careful termination at both ends of the attenuator and output cable system provides a uniform impedance of 17 ohms under all conditions. Reliable impedance characteristics are of special importance in an instrument intended for use as a standard of output voltage.

The meter marked "Output" in the photograph serves to monitor the signal amplitude by reading a reference value of oscillator grid current. This permits standardization of the oscillator performance at any frequency of operation.

In the 86-108 mc FM band, such problems as image rejection, adjacent channel interference and susceptibility to impulse noise have not, as yet, been thoroughly explored. The relation of all these factors to FM receiver design should be investigated in the laboratory before large scale production is attempted. The instrument described is one link in the chain of special instruments required for this purpose.

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MP MASTER
MA25118